Abstract. One of the most important features of the EIT resonance is its very narrow line. Moreover, this resonance can be centered at a magnetically insensitive transition of a hyperfine manifold whose frequency is one of the best Nature's frequency etalons. Combination of these two factors suggests using EIT as an optical bandpass filter in and optoelectronic oscillator, which then will become a very precise clock. We have demonstrated the operation of a proof-of-principle table top device and now focus on building a miniature, ultimtely chip-size, version.

The idea of using optical resonances as frequency standards for making better clocks is well known. Optical technology offers many advantages over all-RF technology in this respect, which has lead to emerging of a variety of different approaches to optical clocks. Our approach combines using the electromagnetically induced transparency (EIT) in ^{87}Rb vapor with the opto-electronic oscillator (OEO) technique.

In a generic OEO scheme, light from a laser is amplitude-modulated by an electro-optical modulator and then is sent into a fiber delay line followed by a photonic filter and a photo detector. The microwave signal from the photo detector output is amplified and fed back into the modulator. The system oscillates if the amplification in the closed loop exceeds the loss. The function of the optical delay in an OEO is to store the microwave energy, in which sense it is equivalent to a microwave cavity in the usual high frequency oscillators. The longer is the fiber, the higher is the quality factor Q. However, a long optical delay line supports many microwave frequencies carried by the optical beam. A narrow band pass photonic filter following the delay line allows for selecting a single RF frequency and helps to achieve a stable single mode operation.

Earlier implementations of the OEO systems in our lab have shown that they have very good stability and are in general very robust devices. It has been suggested than that a photonic filter in the optical channel can be implemented as an EIT system. Utilizing a “clock” m=0 -> m=0 transitions between the F=2 and F=1 ground state manifolds in ^{87}Rb, one may expect to achieve not only good stability, inherent to the OEO devices, but also a good absolute accuracy. Furthermore, such a system does not need any cryogenics or high optical powers. Potentially, it does not even need RF amplifiers, as the RF signal from the photo detector can directly drive the modulator, if the latter has sufficiently high efficiency. Towards this goal, we have designed and build whispering gallery mode based electro-optical modulators that require microwatts of the RF power to produce over 10% sidebands.

All these considerations lead us to believe that an OEO clock can be made very compact and have low power consumption, eventually allowing for a chip-size implementation. Presently, we are developing a table-top version of an OEO atomic clock. While the key elements of this setup, the modulator and atomic cell, are already quite compact (see Fig. 1), the advantage of the table-top implementation of an OEO clock at this stage is in its versatility.

Figure 1. Our Rubidium cell with a temperature sensor (on the left) and with a non-magnetic heater (on the right).

Before building the final version of the OEO clock, we need to explore a huge parameter space and determine the best way of utilizing the EIT filter. One of the most important dilemmas here is using a sideband and the carrier as the pump and probe in the EIT system vs using two sidebands. Investigating the former approach, we have obtained the complex response function of the EIT filter. Analyzing this function we find the phase and amplitude of the EIT signal, see Fig.2. The central peak in Fig. 2 corresponds to the clock transition $\Delta m = 0$. We see, that the EIT on this transition serves as a phase and amplitude filter tat is a few kHz wide. However, in the active systems oscillation linewidth is known to be much narrower than the filter function. Our preliminary tests yielded approximately 100 Hz, which can be made still narrower with appropriate optimization.

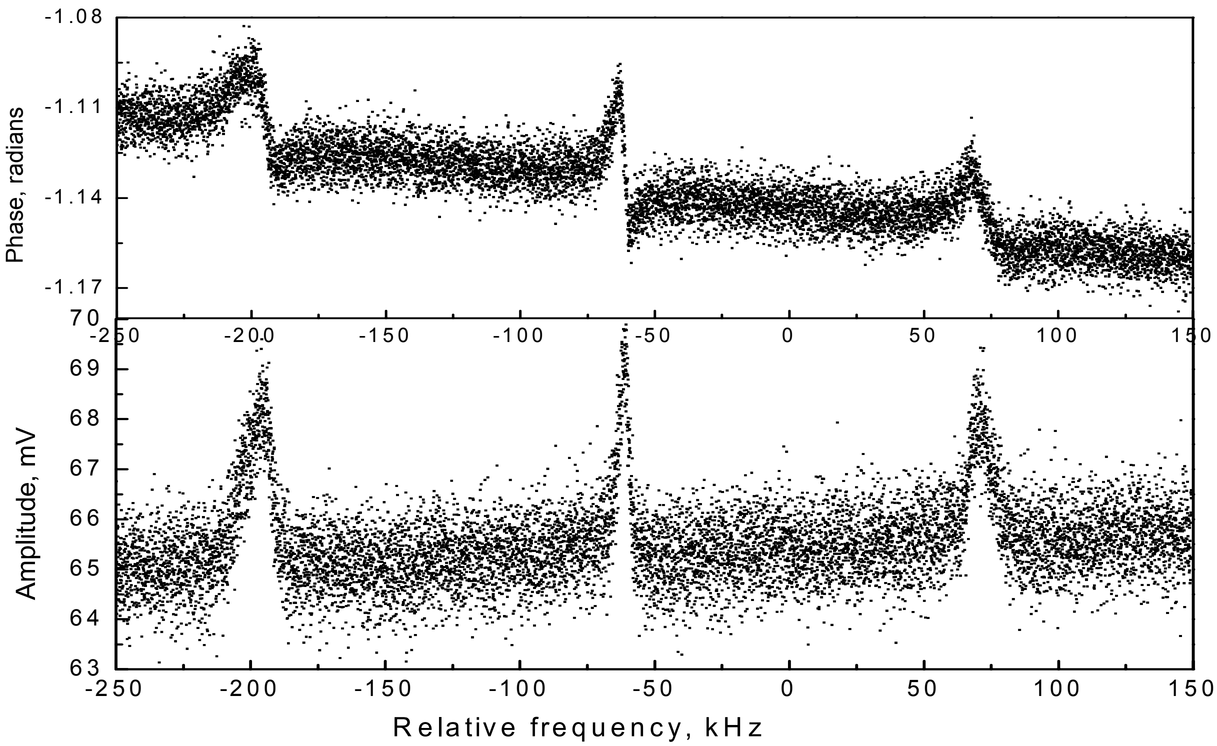

Figure 2. Characterization of the Rubidium cell shown in Fig. 1 as a phase and amplitude EIT filter for an OEO clock. The central feature corresponds to the clock transition Δm = 0, the left and right features correspond to the Δm = +1 and –1 transitions (sensitive to magnetic field).